Multiproduct Plants

Edited by Joachim Rauch

Translated by Karen du Plooy

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Contents

Preface

Those contemplating the use of plants suitable for the production of a number of products will soon find that the body of literature in this area is rather limited. Especially questions related to plant design or the technical equipment for such plants will usually remain unanswered, as there are very few contributions from the chemical industry on this subject.

This state of affairs as well as the encouraging response to a lecture on the different designs and technology of multiproduct plants given at the annual meeting of the GVC (Gesellschaft für Verfahrenstechnik und Chemie [Process Engineering and Chemical Engineering Society]) in Aachen in 1994 has motivated the editor of this book to convince colleagues who are recognized experts in their areas to collaborate on a book on multiproduct plants.

That the concepts and definitions used in this area should be right at the beginning of the book was already obvious during our early discussions. The outcome is collected in Chapter 1, which is followed by descriptions of typical applications of multiproduct plants in Chapter 2. In the next chapter, Chapter 3, the different types of multiproduct plants, subdivided from our point of view, are presented. New developments, such as the pipeless plant concept, are also covered.

It will soon become clear to the reader progressing through the book that the authors of the later chapters always refer back to these different plant concepts, that is, the concepts of the different types of multiproduct plants are used as the central reference point of the book. It is therefore recommended that the sections covering the basic concepts (Chapters 1 to 3) are read before the later chapters.

Our approach to the themes related to multiproduct plants is clearly technical, as shown by Chapters 4 to 11. That contributions on plant organization and the management of multiproduct operations are lacking, may be regarded as a shortcoming. At this point, I would like to express my hope that these interesting themes will be taken up at a later stage.

Many of the authors writing on their specific technical areas have found it useful to aid the reader's comprehension by first introducing the area in general, before continuing with the special aspects relating to multiproduct plants.

For illustrating the machinery, apparatus, and piping and connection technology applied in multiproduct plants, examples of well-established technical components available from suppliers of machinery, apparatus, and plant hardware, were

thought to be useful, because important developments in this area have resulted particularly from efforts on the supplier side, so that a variety of technical solutions are now on offer. Only a small selection of components and systems is described here, and our choice is therefore not claimed to be comprehensive. The selection does, however, demonstrate the impressive innovation drive of the manufacturers.

From the final chapter, on the choice and optimization of multiproduct plants, it is clear that many multiproduct plants are not the natural outgrowth of choice, but that they were dictated by need. It is when dedicated plants do not run to sufficient capacity, because sales were lower than expected, or when the life cycle of a chemical reaches an end and smaller quantities are produced, that the operator is faced with the question of whether the plant can also be used for other products. In this chapter, an attempt is made to present the numerous criteria relevant to these considerations.

I thank everyone who has contributed to this book being accomplished. I thank Prof. Dr. Frey for encouraging me to address the theme of multiproduct plants. My thanks are especially due to Prof. Dr. Wintermantel, who provided the stimulus for this book.

Ludwigshafen, Autumn 2000 J. Rauch

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Part 1
Basic Concepts

1
Definitions of Multiproduct Plants and Flexibility Demands

1.1
Definitions and Concepts

Multiproduct plants are process plants that can, according to market demand, produce various products. Multiproduct plants are used in the chemical, pharmaceutical, and related industries.

Several different types of plants are considered to be *multiproduct plants*:

In the literature [1.1, 1.2], the concept *multiproduct plant* is used, on the one hand, for a plant that uses a very similar process for the sequential production of different, but generally similar products, belonging, for example, to the same product family. These plants are designed and built, in the first place, for a limited number of products. In reference [1.3], for example, the designation *multiproduct plant* is used exclusively, and more narrowly than we prefer, for this type of plant. The basic type of plant represented in Fig. 1.1 is according to reference [1.2] a *single-line plant*. The small boxes labeled a–f in Fig. 1.1 represent separate process steps or equipment (groups), in which certain unit operations take place.

A second definition of a multiproduct plant (multiline/multipath/network type in Fig. 1.1) includes plants that can produce various products by different processes. This occurs, typically, sequentially, but can also run parallel, where different sections of a plant separately produce different products. For this, the multiproduct plant is divided into independent plant sections. This type of plant is also known as a *multiline/multipath* plant [1.4]. The structure of such a plant is oriented according to the unit operations that are carried out in it. Here the products to be produced may often place completely different demands on the equipment and machinery used. In the literature, this type of plant is often termed a *multipurpose plant* [1.1–1.3, 1.5, 1.6]. Typical for this situation is that the operation units may have different uses and may be circuited according to the technical demands of the process for the product to be manufactured.

In the U.S. literature, the very fitting designation *multipurpose pilot plant* is used for a special type of multiproduct plant [1.7]; the term *general-purpose pilot plant* is also used [1.8]. These refer to multiproduct plants that operate on pilot scale, and are used for process development as well as for producing samples and new products in the quantities required for their introduction into the market.

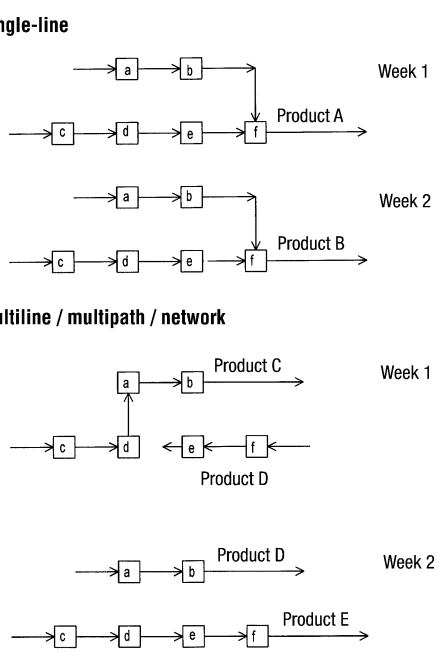

Fig. 1.1 Basic types of multiproduct plants, as outlined in reference [1.2] (reproduced with the kind permission of Butterworth Publishers)

It is true that large, continuously operated single-line plants, for example, steam crackers, may also produce more than one product. In such a case, the product mix that leaves the plant may be determined partly by the market (the buyer). In such a plant, one process is used to produce various linked products simultaneously. Such plants are, however, not multiproduct plants according to our definition, since the same product spectrum, even when in a different composition, is produced in such a plant. A discontinuously operated plant, in which the same product spectrum is produced in every charge, is also not a multiproduct plant. These plants are monoplants.

The often used designation *multipurpose plant* is not used in this book, as all the plants considered here serve only one purpose, that of producing products. Only pilot plants serve an additional purpose, that of process development.

A term that has been in recent use is that of *multisubstance plant*. This term appears to originate from the substance-based concepts embodied in the German law on the control of air pollution (BImSchG). The expression *multiproduct plant* has, in contrast, found its way into the NAMUR recommendation NE33 [1.4].

Changing the production with regard to the type and quantity of product produced should not be associated with any or much additional effort or expenditure. Because of the small capacities required and the high flexibility demands, multiproduct plants are often batch plants [1.9]. Even multiproduct plants that operate mainly continuously often have large, discontinuously operated parts.

1.2 Flexibility Demands of Multiproduct Plants

An important characteristic of a multiproduct plant is its flexibility in being adapted to changing requirements. This is because multiproduct plants are employed when the quantity in which the desired product is required is too small to make its production in a monoplant economically feasible. Multiproduct plants are also useful for producing products whose variable market makes the running of a monoplant unfeasible and for the production of several products of similar type (belonging to the same product "family").

In none of these cases is it possible for the plant designer to produce a tailor-made plant, that is, to build a plant that exactly fulfills the requirements for the manufacture of a precisely determined product in a predetermined quantity by a process optimal for this product.

When the products to be manufactured and the processes that are to be carried out in the plant are known, it simplifies matters. It does, however, remain unclear which product is to be produced in which quantities and in what time frame, and if it is to be produced together with other products. As with monoplants, multiproduct plants can, however, be product-oriented or – from the point of the view of the process engineer – be process-oriented. A multiproduct plant that produces products belonging to the same family is such a case, corresponding to the single-line case shown in Fig. 1.1.

It is more difficult to plan and operate a plant that should also produce products not known at the building stage. In such a case, not all the requirements placed by the technology of the process and the properties of the substances are defined. Only the equipment that is required can be considered in the planning of such a plant (equipment-oriented planning). This means that a plant is constructed that contains the equipment suitable for certain unit operations; such a plant can then be used within a wide range of process parameters. This corresponds to the multiline/multipath/network type of plant in Fig. 1.1.

In a publication by Gruhn and Fichtner [1.10], different flexibility types are identified; of these, three types of flexibility are especially important in multiproduct plants:

- *Structural flexibility.* This is the type of flexibility that allows a system, through changes in the connections between its elements, to adapt to changed demands in function. In this way, different processes can be carried out if the connections between the different pieces of equipment in which specific basic operations are carried out are changed.
- *Product-assortment flexibility.* This is the ability of a system to produce different products without the system needing to be changed substantially. This type of flexibility is especially important for multiproduct plants that are used for the production of families of products.
- *Flexibility in capacity.* Such a system can accommodate different capacity demands.

These flexibility types are represented in Fig. 1.2 [1.11].

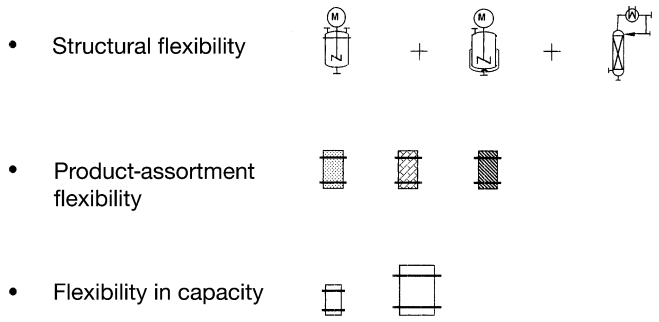

Fig. 1.2 Different flexibility types in process plants

Various technical concepts have been developed in the past to meet these flexibility requirements in multiproduct plants.

The flexibility concepts introduced here will be developed further in Chapter 3 (Concepts).

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2
Application Areas

2.1
General

Multiproduct plants are found everywhere in the chemical industry where products in small market quantities but high added values are produced. The yearly production of such products is roughly a few hundred tons, and such products generally have a value of 5–500 Euros/kg. In contrast, bulk products produced in the chemical industry in continuously operating monoplants have market shares of millions of tons per year and their price is typically in the range of 0.5–2.5 Euros/kg.

The typical application areas of multiproduct plants are therefore in the production of fine chemicals, specialty chemicals, and active substances, as well as pharmaceutical agents. Apart from that, such plants are also used to manufacture products according to special requirements for a client. This is, for example, the case with special dyes, plastic blends, or dispersions [2.1–2.3].

Multiproduct plants enable the supplier of the products described above to react quickly to market demands and to fulfill clients' wishes "just-in-time." A multiproduct plant may be comparatively larger and be working to fuller capacity than the corresponding monoplant for an individual product. Someone who runs a multiproduct plant therefore profits from the cost reduction resulting from this.

Small-scale multiproduct plants are also suitable for process development and validation, as well as for the production of samples of new products [2.4, 2.5].

2.2
Research and Development

Multiproduct plants are widely used as pilot plants for research and development. They serve the purpose of process development, dealing with scaling-up questions, and producing samples. Such a pilot plant is referred to in the U.S. literature as a "multipurpose pilot plant" [2.4] or a "general-purpose pilot plant" [2.6]. The pilot scale at which these plants produce is greater than laboratory scale and smaller than that of production plants. Multiproduct plants serve as one of the

tools paving the way from the product conception to the construction of the production plant (see Fig. 2.1).

The first phase after the conception of the product idea is that of process screening, where alternative synthetic routes and processes are tested, within the confines set by the requirements and objectives of the project. Laboratory methods and microunits are the tools utilized during these orientational experiments.

In the process development phase, during which the chosen concept for the process is checked, tests are carried out in integrated miniplants [2.7] or in research and development (R&D) multiproduct plants. Small quantities of product already need to be produced during process development, for example, for toxicological or clinical testing in the case of active substances. Miniplants and multiproduct plants are standard parts of research pilot plants.

In the third phase, that of the design of the production plant, the final production process is optimized. Individual equipment that may be scaled up or multiproduct plants are used for working out the dimensions of the equipment and machinery for production.

Once a production process has been decided upon, the product's rapid introduction into the market is of prime economic importance. Multiproduct research pilot plants can play an important role here too.

To keep up with increasing international competition, one needs to keep the time between product idea realization and market introduction as short as possible. This is done by so-called simultaneous engineering, by which the above-described phases of process development overlap as much as possible.

Multiproduct plants used in research need to be versatile, to be able to continuously adapt to the different processes associated with the production of products with different chemical and physical properties. Whereas the development and construction of multiproduct plants used in production are often product-oriented, with known product families produced by similar processes in mind, the planning of multiproduct plants for research need to be technology- and equipment-oriented. This means that the equipment and machinery need to cover certain ba-

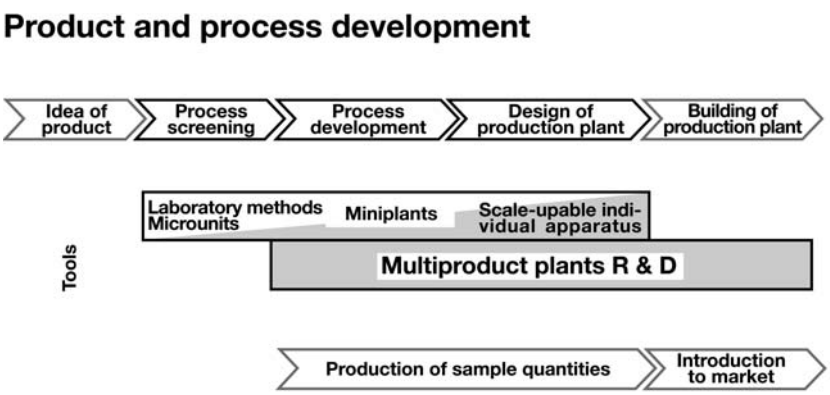

Fig. 2.1 Phases in the development of products and processes